Grating Fabrication for Gravitational Wave Interferometers and LISA GRS

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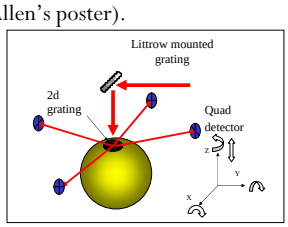
Motivation for Gratings

- Tip/tilt sensing. Lisa requires 100 nanorad/$Hz^{1/2}$ of resolution in angular sensing.
- Littrow-mounted double-sided grating for displacement sensing (see Graham Allen's poster).

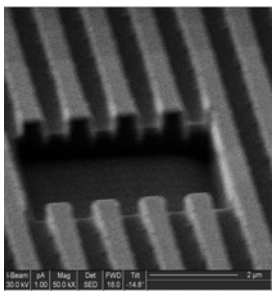


The two-dimensional grating for angular sensing. A Littrow-mounted grating is added to form a displacement sensor using grating cavity resonance.

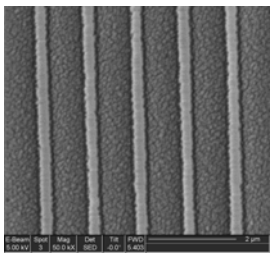
- Lithographic marks for determining orientation and altitude (keeps track of bumps and irregularities).
- High power gratings for Ligo III and BBO.

Dielectric Gratings

- Centimeter scale gratings have been fabricated on quartz and fused silica.
- E-beam lithography was performed on ZEP520A resist.
- Quartz was etched using CHF_3/O_2 gases in a reactive ion etcher.
- 933 lines/mm, 300nm etch depth.
- Ability to control etch depth and duty cycles.



SEM of a 50% duty cycle dielectric grating displaying a cross-sectional view.



SEM of a 25% duty cycle dielectric grating

Au Gratings – Imprinting

- Goal: putting gratings on the outer gold coating of the proof masses.
- Key problem: proof masses do not fit in standard optical, e-beam, or nanoimprinting lithography tools.
- Our approach: leverage existing lithography tools to create dielectric grating stamps and then to use imprinting to pattern the proof masses.

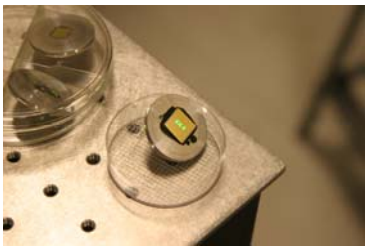
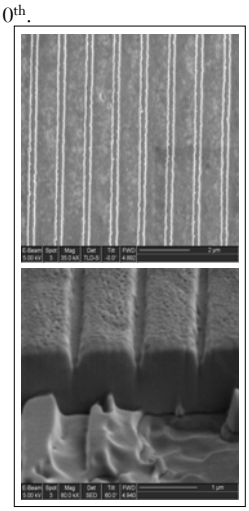
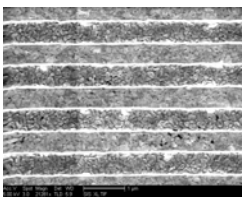


Photo: Imprinted gold gratings, 75% duty cycle.

- Yield stress of gold: 250 MPa – 1 GPa. (100 – 400 lbs over a 2mm x 2mm area)
- 50% and 75% gold gratings imprinted using a hydraulic press on a tungsten substrate.
- Diffraction efficiencies measured to be 26% for the first orders and 36% for the 0^{th}.



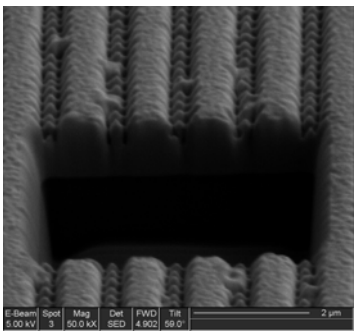
SEMs of 75% duty cycle imprinted gold grating. Cross-sectional view on bottom.



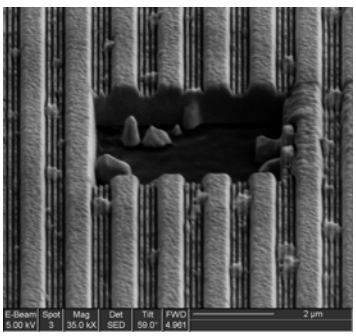
SEM of a 50% duty cycle imprinted gold grating.

Au Gratings – FIB Writing

- Used an FEI focused ion beam machine.
- Milling achieved using bombardment with Ga^+ ions
- Fabricated millimeter-sized grating in 6 hours (using 3000pA aperture).
- Measured diffraction efficiencies: 18% in the first orders, 59% in the 0^{th}.



SEM of an gold grating milled in a FIB. Cross-section is shown.



Milled grating using twice as many "pixels."

Future Work

- Nanoimprinting—requires less force
- Fabricating two-dimensional patterns
- Two-sided dielectric gratings
- Improve grating quality, thus decreasing random scattering.
- Develop high power gratings.

Conclusion

- Grating patterns made on dielectrics and gold.
- Diffraction efficiencies measured to be suitable for tip/tilt and displacement sensing.

Collaborations

- Jet Propulsion Laboratory DRDF (LISA)
- Lawrence Livermore National Laboratory (high power gratings)